Summary Report
2006 ERSP Workshop on Linking DOE Science and Remediation Decisions

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Supporting fundamental scientific research on subsurface contaminant transport in order to inform environmental management decisions at U. S. Department of Energy (DOE) facilities is one of the tenets of the Environmental Remediation Sciences Program (ERSP), administered by the Environmental Remediation Sciences Division (ERSD) within the Office of Biological and Environmental Research in the DOE Office of Science. However, transferring knowledge and tools developed during fundamental research to those charged with making and implementing remedial decisions (i.e., "problem holders") is not straightforward. Major stumbling blocks include difficulties in communication between researchers and remediation managers, different priorities, and schedule constraints. In June 2006, a workshop was held in Idaho Falls, ID to bring together ERSD-funded researchers and DOE problem holders for discussions on how science can impact decisions. The goal was to help the scientists better understand how to maximize the value of their research to those charged with making decisions about DOE contamination problems, and to familiarize the problem holders with some of the current and future tools available to support technically sound remediation decisions.

Approximately 25 researchers (primarily associated with DOE national laboratories and universities) met with representatives from DOE headquarters, the DOE field office in Idaho, and Idaho National Laboratory (INL) cleanup contractors. Representatives from the U. S. Geological Survey (USGS), the U. S. Environmental Protection Agency (EPA) and the Idaho Department of Environmental Quality also participated. The total number of workshop attendees was around 50. The agenda included presentations on the needs of DOE's Office of Environmental Management (DOE-EM), a review of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process that prescribes remedial decision making at many DOE sites, evaluation of monitored natural attenuation of inorganic contaminants, specific examples of research directly supporting cleanup activities at a number of DOE facilities, and a tour of the INL site. The INL site was used as a source of case studies, in which specific remediation challenges were described. In breakout sessions workshop attendees worked together to identify the most important scientific challenges underlying some of the critical cleanup problems, suggest research agendas that could address these challenges, and explicitly define how results from the research could be used by problem holders. A strong emphasis was placed on producing quantitative information (e.g., kinetic parameters, system properties, functional relationships) that could be used directly in computational fate and transport models that are used to evaluate risk and potential remediation strategies. A brief summary of some of the workshop highlights and conclusions are presented here; interested readers are invited to visit the workshop website at http://www.inl.gov/conferences/ersp/, where links to the presentations are available.

The immense scale of the challenge facing DOE-EM was emphasized by Lawrence Bailey, the director of EM's Office of Groundwater and Soil Remediation. The estimated environmental liability of the Department of Energy was $181.7 billion in fiscal year 2004, accounting for almost three-quarters of the federal government's total environmental liabilities. Groundwater contamination resulting from DOE activities exists in over 20 states at more than 60 different sites. Trichloroethene is the most common groundwater contaminant, but equal and in some cases greater technical challenges are associated with the cleanup of inorganic contaminants, particularly Tc-99, Sr-90, Cr, and U. Robust and reliable methods of remediating Technetium-99, Strontium-90, and Uranium contaminants are not available. Significant uncertainty also exists with respect to the conceptual and computational models used to predict the subsurface fate and transport of these contaminants. Source term and site characterization would also benefit from new technical approaches. Mr. Bailey indicated that his office was particularly interested in research specifically targeting these problems, and he looked forward to improved coordination and communication between the ERSD and EM. John Zachara of the Pacific Northwest National Laboratory described a model for science and technology research coordination with problem holders at the Hanford site that he and collaborators have successfully implemented. Among examples he cited were determining mechanisms that account for faster than expected Cs migration at the SX tank farm, anomalous absence of Tc-99 in groundwater near the BC cribs, and the stability of a U(VI) plume in the 300A area. He emphasized that scientists themselves must take responsibility for problem resolution, and that research must be "on-target…. Relevance is not good enough." Research products must be immediately useable by problem holders, and conceptual models must be transferable to practical computational models. Conceptual models that cannot be captured in workable numeric models are not useful.

The enormous volumes and inaccessibility of much of DOE's subsurface contamination has led to increasing interest in the concept of monitored natural attenuation (MNA). Although MNA is currently an accepted solution for a number of organic contaminants under certain scenarios, its application for inorganic contaminants is still nascent. Robert Ford of the U. S. EPA National Risk Management Research Laboratory in Ada, OK discussed technical considerations for evaluation of MNA for inorganic contaminants in groundwater. The message was that, contrary to its perception amongst many members of the public as a "do nothing" approach, MNA in fact requires a substantial scientific investment in order to demonstrate that the fate and transport of a contaminant at a specific site is understood and predictable, and that the timescale of the attenuation process is consistent with regulatory requirements for site remediation. The primary processes applicable for inorganic contaminants are immobilization and radioactive decay. In the case of immobilization, MNA proponents must also assess the susceptibility of the contaminants to re-mobilization in the event of changes in site geochemistry. Dr. Ford described a tiered approach for evaluating MNA in groundwater at a specific site, consisting of 4 phases: (1) Demonstrating active contaminant removal and plume stability; (2) Determining the rate and mechanism of attenuation; (3) Determining long-term capacity for attenuation and stability; and (4) Designing a monitoring program, defining triggers for MNA failure, and establishing a contingency plan (Reisinger et al. 2005). He emphasized the importance of understanding the hydrogeologic conditions at a site, so that reaction times can be compared to transport times, of independently evaluating contaminants in mixed plumes, and of considering the radionuclide-specific decay chains and daughter products. In summary, workshop participants were reminded that building the scientific foundation for MNA represented an area where collaboration between problem holders and researchers presented tremendous opportunities.

A diverse set of examples of research projects supporting specific site cleanups was presented, from site characterization at Hanford (Mayes), to post-cap monitoring at Oak Ridge National Laboratory (Jardine), to assessment of the role of microbes in trichloroethene (TCE) remediation at the INL (Colwell). In the latter case, research funded initially jointly by EM, the Office of Science through the Environmental Management Science Program, and the Idaho Water Resources Research Institute and then subsequently by ERSD led to amendment of a CERCLA Record of Decision (ROD) for a TCE plume at the INL's Test Area North (TAN). As a result of the biogeochemical research that included demonstration of natural attenuation, the original pump and treat strategy was replaced by *in situ* bioremediation and natural attenuation for the source zone and plume fringes, respectively (Sorenson 2000; Sorenson et al. 2000; Newby et al. 2004). Colwell explained that critical factors in the success of the research-operations partnership were the receptiveness of INL operations personnel to new ideas, the commitment of researchers from multiple disciplines and institutions to work together to solve a real environmental problem, and a willingness on both sides to tackle formidable logistical and administrative barriers (e.g., resolving conflicts in research and regulatory timelines, balancing the high cost of collecting and disposing of CERCLA-regulated samples with scientific needs).

In large part because of the success at TAN, the value of research has been recognized by the cleanup management at the INL. Consequently INL cleanup managers were supportive of the goals of the workshop and helped to identify specific INL issues which could potentially benefit from additional scientific understanding. For the workshop, the following three issues were used as case studies for workshop participants to discuss: (1) Subsurface fate and transport of ^{90}Sr at the Idaho Nuclear Technology and Engineering Center (INTEC); (2) Fate and transport of Pu at the Subsurface Disposal Area (SDA); and (3) Development of a site-wide groundwater model that can integrate currently independent models developed for the various INL CERCLA "waste area groups" (9 total). For each of the issues, CERCLA regulatory frameworks already exist, and the constraints imposed by the CERCLA process were introduced by INL representatives. Yet opportunities for research input still exist, and identification of these opportunities was an important objective of the breakout groups. Brief summaries of the breakout group discussions are presented below.

Fate and transport of ^{90}Sr *at INTEC*. INTEC was the former site of spent nuclear fuel reprocessing. During these activities, liquid releases directly to groundwater and vadose zone alluvium occurred; the latter pathway was predominant in terms of the radioactive contaminant load. The major contaminant of concern with respect to the Snake River Plain Aquifer (SRPA) is ^{90}Sr. Current ^{90}Sr concentrations in the aquifer directly under INTEC are approximately 3 times the U. S. EPA Maximum Contaminant Level (MCL) of 8 pCi/L, but a bigger threat may stem from the ^{90}Sr that remains in the vadose zone above the aquifer. Measurements of ^{90}Sr in perched water bodies that lie below INTEC and above the SRPA (approximately 137 mbls at INTEC) have been as high as 50,000 times the MCL (DOE 2006). The CERCLA compliance standards for INTEC require that no contaminant exceed its MCL in the aquifer after the year 2095. Current modeling predictions indicate that this goal will not be met for ^{90}Sr in the absence of engineered remedial actions. The proposed remedy relies on infiltration controls including a cap, and if these are inadequate the contingent remedy is pumping and treating of the aquifer (DOE 2006). The ROD for the site is expected in spring 2007, and incorporation of significant additional scientific input is unlikely by then. However, because CERCLA requires 5 year reviews to evaluate remedy effectiveness, an opportunity still exists for scientific impact. Significant uncertainty exists with respect to the mass balance of the below-ground inventory of ^{90}Sr, as distributed between the surficial alluvium, perched water bodies, sedimentary interbeds, and basalt flows. Predicting hydrologic flow in this complex physical system and understanding the geochemical behavior of the ^{90}Sr are enormous challenges. The breakout group agreed that a science program in support of the INTEC ^{90}Sr problem should be focused on both near- and long-term objectives. In the near term, better support of the existing conceptual and conceptual model for ^{90}Sr transport at INTEC was needed, and could be accomplished through more detailed characterization of existing alluvium core material from the major release area, replicate release experiments in the lab, and additional field data collection. Over the longer-term, evaluation of innovative methods to intercept or immobilize ^{90}Sr above the water table was recommended.

Fate and transport of Pu at the SDA. The SDA is a 97-acre site at the INL that was used for landfill disposal of transuranic, mixed transuranic, and other radioactive waste from 1954 until 1970. The SDA is part of the larger Radioactive Waste Management Complex (RWMC) site, which also includes above-ground waste storage. After 1970, nontransuranic mixed waste disposal continued, but since 1983 only low-level waste has been allowed. Much of the buried waste at the SDA originated at the Rocky Flats Plant, the former nuclear weapons production facility in Colorado. Eighteen different contaminants were identified by the CERCLA remedial investigation (RI)/baseline risk assessment (BRA) as contaminants of concern for human health based on a 1,000 yr simulation, including twelve radionuclides and six nonradionuclides. Surface soil exposure pathways posed the greatest potential risk, but the analysis also identified eight contaminants as possible groundwater ingestion risk drivers in the future. These include ^{14}C, ^{99}Tc, nitrate and a number of chlorinated solvents (Holdren et al. 2006). Pu isotopes 238, 239 and 240 were not determined to be a threat to groundwater, but because of public perception, any hints of Pu subsurface mobility are notable. Almost all (90+%) of the Pu in the SDA is derived from Rocky Flats solid waste debris. Detections of Pu in perched water zones at the SDA are rare (<3% of samples have detected Pu), and aquifer detections are even rarer and may in fact be false positives. However, confirming false positives for Pu in the samples is difficult. If they are true detections, then the challenge is to explain how the Pu moved so much more quickly than predicted based on studies of

Pu immobilization in sediment columns. One possibility is that the Pu moved as colloids, either as intrinsic colloids (colloids composed of Pu oxides) or as a Pu sorbed to colloids composed of other material, such as clay particles. Much of the breakout group discussion focused on how to properly sample and characterize subsurface colloids, and how to determine whether colloids in solid and liquid samples were mobile at the time of collection; because waste will remain in place once the site is closed, implementing a defensible monitoring program will be critical to reassure stakeholders that remedial actions are protective. Sampling for natural subsurface colloids is a topic that has not yet received sufficient attention; the potential for artifacts is high, and rigorous protocols have not yet been standardized. The breakout group agreed that testing of field sampling methods is a high priority, in conjunction with field-scale colloid tracer tests. In addition, it will also be necessary to develop appropriate colloid transport modules that can be incorporated into the overall contaminant fate and transport models to be used for future applications, such as designing monitoring programs and assessing the effectiveness of remediation.

INL site-wide groundwater model. Groundwater flow and contaminant transport numerical models are in use at each of the contaminated facilities at the INL. Some of the models include vadose zone components as well. These numerical models, in addition to other subregional models for the SRPA developed by the USGS and others, are not necessarily consistent. They were all developed for different specific objectives, and rely on different conceptual models, codes, and grid dimensions. However, for long-term stewardship DOE will need a comprehensive model to evaluate the cumulative impacts of INL operations on the SRPA. The INL is therefore currently developing a site-wide groundwater model, incorporating features from the other models as well as new knowledge, for use as a comprehensive aquifer management tool. It is a significant challenge, because of the complexity (fractured basalt aquifer, where the fractures are believed to conduct much of the flow, overlain by a very heterogeneous and deep vadose zone) and size of the region to be captured (the INL itself is 890 square miles; the model covers over 2000 square miles). The field data are sparse, in large part because drilling wells to access the deep aquifer is so expensive. Available wells are concentrated in and around the major facilities, and between the facilities very few data have been collected. The intent is to build a 3-D model, but the majority of available data is 2-D. The breakout group discussed the problem of identifying a representative elemental volume, and agreed that research into robust approaches for scaling system parameters (particularly dispersivity) measured at the 10 -100 m (facility-scale) scales, for use at the 1-100 km scales was a critical need. Additional field data must also be collected for supporting the conceptual model, and for calibrating and testing the numerical model. Biogeochemical processes are currently not adequately represented in the model; additional research to identify critical processes and approaches to incorporate them into the model are needed.

The research topics identified in the breakout sessions were broadly consistent with the programmatic focus of the ERSP. The important outcome of the discussions was that participating researchers were able to see explicitly how such research was directly applicable to a specific DOE need, and DOE problem holders were provided with specific examples of research that would directly benefit them in making decisions. The major conclusions of the workshop were that for effective linking of science and cleanup, the following are required: recognition on the part of cleanup staff that additional understanding reduces uncertainty and helps to improve long-term risk-management strategies, recognition on the part of researchers that their products must be immediately useful, and synchronicity between required decisions and research outputs. Effective communication between research scientists and cleanup personnel is critical. By working together, it is possible to further the DOE missions for both the advancement of science and the proper management of environmental legacies.

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